BERKELEY LAB
Environment, Health & Safety Division

May 25, 2004
DIR-04-054

Mr. Richard Nolan
Department of Energy
Berkeley Site Office
Berkeley Laboratory
1 Cyclotron Road, MS 90R1042
Berkeley, CA 94720

Subject: **Radionuclide Air Emission Report for 2003**

Dear Mr. Nolan:

I'm pleased to present, for DOE Site Office certification, Berkeley Lab's Radionuclide Air Emission Report for 2002, as required by Subpart H of 40 CFR Part 61 of the National Emission Standards for Hazardous Air Pollutants (NESHAP). Please note that the calculated dose of 0.01 mrem (0.0001 mSv) from Berkeley Lab airborne emissions in 2003 is well below the dose standard of 10 mrem/year (0.1 mSv/year).

After signing the certification statement (located on page 37), please forward a copy of the certification page to Ron Pauer (MS 75B0101). If you have any questions on this report, please contact Ron at (510) 486-7614.

Sincerely,

Robin Wendt
EH&S Division Director, Acting

RW:lw

Attachment

cc: w/ Attachment
S. Benson
C. Schwab (DOE)
R. Pauer
P. Thorson
M. Ruggieri
L. Wahl
N. Ware

E.O. Lawrence Berkeley National Laboratory
Environment, Health, and Safety Division
Environmental Services Group

United States Department of Energy

U.S. Department of Energy

Radionuclide Air Emission Report for 2003

(in compliance with 40 CFR 61, Subpart H)

May 24, 2004

Site Name: **Ernest Orlando Lawrence Berkeley National Laboratory**

Operation Office Information

Office:	U.S. Department of Energy Berkeley Site Office	
Address:	MS 90R1023 One Cyclotron Road Berkeley, CA 94720	
Contact:	Carl Schwab	Phone: (510) 486-4298

Site Information

Operator:	University of California Ernest Orlando Lawrence Berkeley National Laboratory	
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Contact:	Linnea Wahl, CHP	Phone: (510) 486-7623

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FACILITY INFORMATION

1.1 SITE DESCRIPTION

1.1.1 Laboratory Operations

The Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab) is a multi-program national laboratory managed by the University of California (UC) for the U.S. Department of Energy (DOE). Berkeley Lab's major role is to conduct basic and applied research in biology, physics, chemistry, materials, and energy. Berkeley Lab, the birthplace of the cyclotron, was founded by the late Nobel laureate, Ernest Orlando Lawrence, in 1931.

Berkeley Lab operates facilities encompassing areas where radionuclides are handled and stored that are subject to the U.S. Environmental Protection Agency (EPA) radioactive air emission regulations in 40 CFR Part 61, Subpart H, "National Emission Standard for Hazardous Airborne Pollutants other than Radon from DOE Facilities" (NESHAP). Figure 1 illustrates the Berkeley Lab general site configuration and locations of buildings.

Radiochemical and radiobiological studies performed at Berkeley Lab typically use millicurie[1] quantities of a variety of radionuclides. All use of radioactive material at Berkeley Lab must be in accordance with an internal authorization or permit. A radiation work authorization is issued for long-term projects that operate under routine radiological conditions; a radiation work permit is issued for nonresearch projects or tasks that require special radiation protection measures. Each authorization or permit is reviewed at least every 18 months, depending on changes to the project. An authorization or permit establishes the location of radioactive material areas (work areas where unsealed radioactive material is handled) and radioactive material storage areas (controlled areas where radioactive material is stored only, with no direct manipulation of the material). Table 1 identifies buildings at Berkeley Lab where handling of unsealed radioactive material was authorized in 2003.

[1] One millicurie (mCi) is equal to 3.7×10^7 Becquerel (Bq).

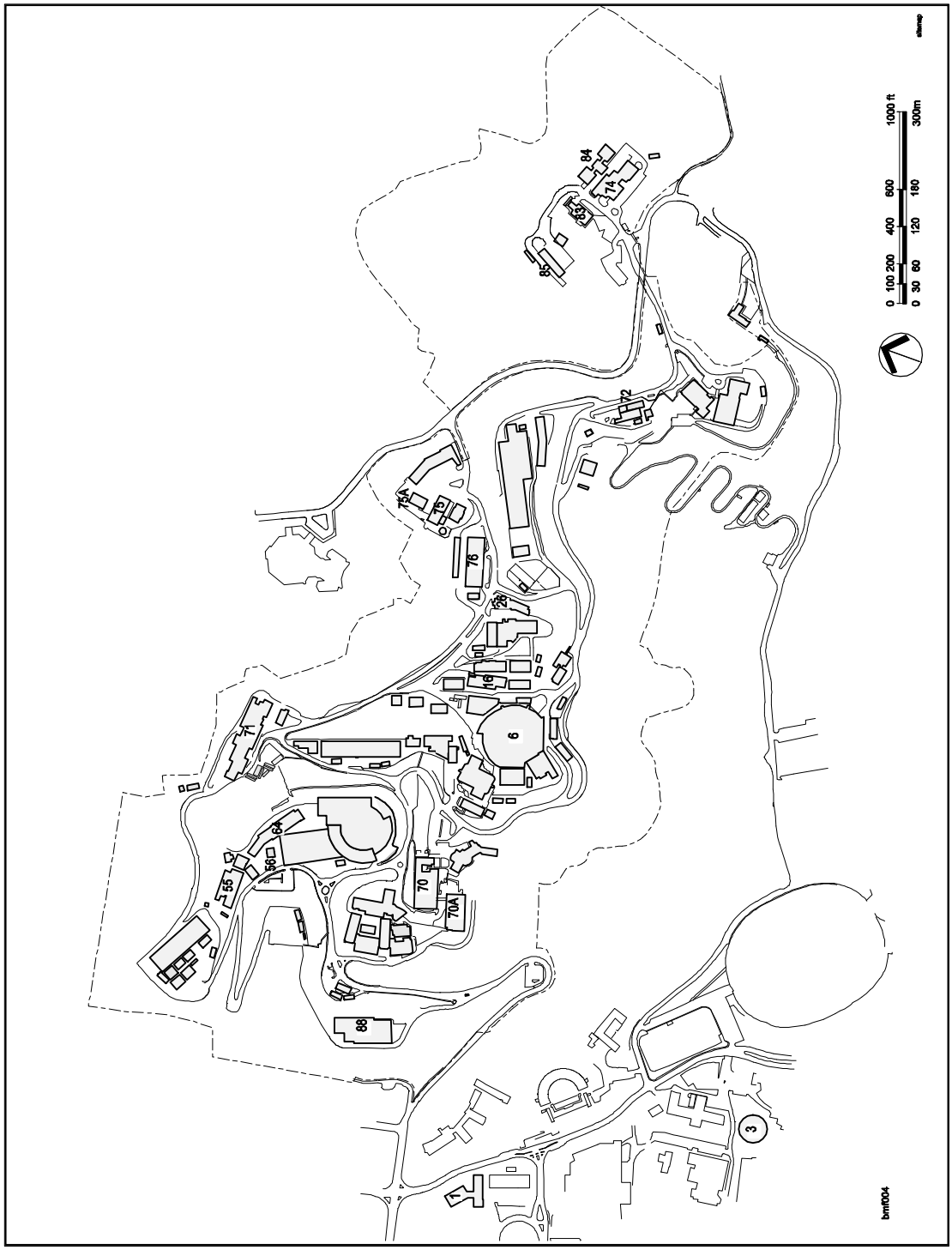

Figure 1 Berkeley Lab Buildings

Table 1 Berkeley Lab Buildings Where Use of Unsealed Radionuclides is Authorized

Building number	Building description or function
1	Donner Laboratory
3	Calvin Laboratory
6	Advanced Light Source (ALS)
16	Accelerator and Fusion Research
26	Radioanalytical Laboratory
55	Center for Functional Imaging and Life Sciences Research
56	Biomedical Isotope Facility
64	Life Sciences Research
70	Environmental Energy Technology and Nuclear and Earth Sciences Research
70A	Nuclear, Chemical, and Life Sciences Research
71	Accelerator and Fusion Research
72	Low-Background Facility
74	Life Sciences Research
75	Former National Tritium Labeling Facility (NTLF)
75A	Former Hazardous Waste Facility
76	Radioanalytical Laboratory
83	Life Sciences Research
84	Human Genome Facility
85	Hazardous Waste Handling Facility
88	88-Inch Cyclotron

1.1.2 Berkeley Lab Site

The Berkeley Lab main site is situated on a hillside above the main campus of UC Berkeley. This 200-acre (80-hectare) site is located on the west and southwest-facing slope of the Berkeley hills, at elevations ranging from 500 to 1,100 ft (150 to 330 m) above sea level within the cities of Berkeley and Oakland. It is located about 3 miles (5 km) east of San Francisco Bay and about 15 miles (25 km) east of the city of San Francisco (Figure 2).

Berkeley Lab is located in an urban/wildland interface zone on land owned by the university. Berkeley Lab is surrounded by university land on nearly all sides. In addition, Berkeley Lab maintains a landscape buffer zone between its facilities and the site boundary. Beyond the northern boundary of Berkeley Lab are university facilities and single-family homes, and beyond the western boundary are multiunit dwellings, student residence halls, and commercial buildings. The area to the east and south, which is also part of the university's lands, is maintained in a largely natural state and includes UC recreational facilities and the UC Botanical Garden. The nearest farm is in Wildcat Canyon Regional Preserve, which is about 2 miles (3.2 km) north of Berkeley Lab, where cattle graze.

The western portion of Berkeley Lab is in the city of Berkeley (population 102,743) and the eastern portion is in the city of Oakland (population 399,484). The population within 50 miles (80 km) of Berkeley Lab increased by about 30% during the 1980s and 1990s from 5 to 6.6 million, as determined by the 2000 census.

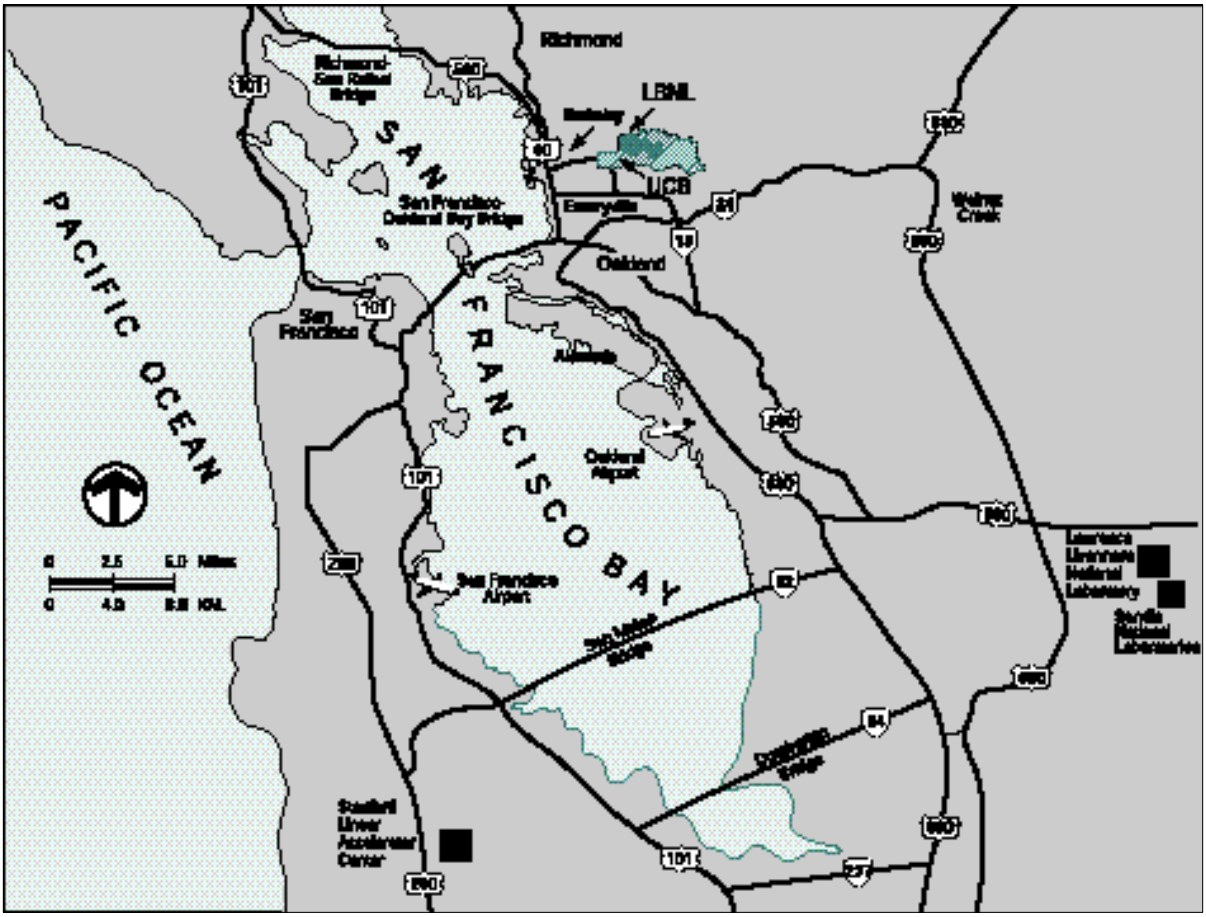

Figure 2 San Francisco Bay Area Map

1.1.3 The Climate at Berkeley Lab

The climate of the Berkeley Lab site is greatly influenced by its proximity to the Pacific Ocean and its exposure to the maritime air that flows in from San Francisco Bay. The climate is also influenced on the east by the hills paralleling the eastern shore of the San Francisco Bay. These physical barriers contribute significantly to the relatively warm, wet winters and cool, dry summers of the site. Seasonal temperature variations are small, with approximate mean temperatures of 63 °F (17 °C) during the summer and 48 °F (9 °C) during the winter. The average annual rainfall is about 29 in. (74 cm). About 95% of the rainfall occurs from October through April, and intensities are seldom greater than 0.5 in./h (1.3 cm/h). Thunderstorms, hail, and snow are rare. Winds are usually light, but summer sea breezes can reach up to 20–30 mph (9–13 m/s). Winds from winter storms can reach speeds of 30–40 mph (13–18 m/s). The predominant wind directions are westerly and northwesterly during fair weather and southeasterly in advance of storms.

1.2 COMPLIANCE STATUS OF BERKELEY LAB

Berkeley Lab has been in full compliance with the requirements of 40 CFR, Part 61, Subpart H, since 1995, when EPA sent DOE written confirmation that Berkeley Lab had satisfactorily completed all requirements of a federal facilities compliance agreement (FFCA). As part of the FFCA, Berkeley Lab formalized all phases of its NESHAP program and proposed a graded strategy for performing emissions measurements required by Section 61.93(b)(4)(i) of the NESHAP regulations. Categories of emissions measurements are determined by the greatest potential effective dose equivalent from airborne radionuclide emissions that could be received by a member of the public at an offsite point where there is a residence, school, business, or office (the maximally exposed individual [MEI]).

Airborne radionuclides could be emitted from any of several locations (release points) at Berkeley Lab, such as stacks atop buildings or radioactive material areas within buildings. Stack release points vent one or more radioactive material areas where emissions must be measured by sampling or monitoring because the potential dose could exceed 0.001 mrem/y. Emissions from other release points are controlled by radiation work authorizations or permits and by periodic evaluation; no monitoring is required because the potential dose is less than 0.001 mrem/y. Table 2 summarizes the EPA-approved NESHAP compliance strategy for emissions measurements that Berkeley Lab has followed since the beginning of 1995 and lists the number of release points in each measurement category in 2003.

Table 2 Summary of NESHAP Compliance Strategy for Measuring Emissions in 2003

Annual effective dose equivalent (EDE) (mrem/y)[a]	Category	Requirements	Number of release points
EDE $\geq$ 10.0	Non-compliant	Reduction or relocation of source term and reevaluation prior to authorization.	0
$10.0 > EDE \geq 1.0 \times 10^{-1}$	I	• Continuous sampling or monitoring. • Telemetry for nuclides with half-lives < 100 h • EPA application to construct or modify.	0
$1.0 \times 10^{-1} > EDE \geq 5.0 \times 10^{-2}$	II	Continuous sampling with weekly analysis.	10
$5.0 \times 10^{-2} > EDE \geq 1.0 \times 10^{-2}$	III	Continuous sampling with monthly analysis.	17
$1.0 \times 10^{-2} > EDE \geq 1.0 \times 10^{-3}$	IV	Sampling annually during project activity.	0
$EDE < 1.0 \times 10^{-3}$	V	Inventory controlled by radiation work authorization/permit and periodic evaluation. No monitoring required.	121

[a] 1 mrem = 1.0×10^{-2} mSv

1.3 SOURCE DESCRIPTION

Berkeley Lab uses a wide variety of radionuclides in its radiochemical and radiobiological research programs. In addition, radioactive gases are a by-product of charged-particle accelerator operations. Radioactive gases produced by accelerator operations in Buildings 6, 56, and 88 include ^{11}C, ^{13}N, ^{15}O, and ^{18}F, which are short-lived radionuclides.

All radionuclides that are authorized for use or storage at Berkeley Lab are considered when evaluating the potential to emit airborne radionuclides. A list of these authorized radionuclides is maintained in the NESHAP files. As required by 40 CFR Part 61, when evaluating potential for emissions, no credit is taken for emission controls, such as filters and other devices that prevent radionuclides from being emitted into the air, and the appropriate EPA-specified physical state factor (provided in 40 CFR Part 61, Appendix D) is applied. Based on the potential to emit airborne radionuclides, the number and location of monitored and sampled stacks subject to each compliance category changes throughout the year in response to changes in research projects. During 2003, 27 stacks at eight facilities at Berkeley Lab had the potential to emit radionuclides into the atmosphere at a level that required sampling under the criteria in Table 2 (Category I–IV). The buildings that these stacks exhaust are listed in Table 3, along with the measurement categories of these facilities in 2003.

Table 3 Buildings with Potential to Emit Airborne Radionuclides in 2003

Buildings with release points	NESHAP Compliance strategy category					Total
	Category I	Category II	Category III	Category IV[a]	Category V	
1	0	0	2	0	7	9
3	0	0	0	0	2	2
6	0	0	0	0	9	9
16	0	0	0	0	1	1
26	0	0	0	0	3	3
55	0	0	1	0	13	14
56	0	2	0	0	0	2
64	0	0	0	0	1	1
70	0	2	3	0	7	12
70A	0	2	4	0	25	31
71	0	0	0	0	4	4
72	0	0	0	0	2	2
74	0	0	0	0	16	16
75	0	0	5	0	5	10
75A	0	0	0	0	1	1
76	0	0	0	0	1	1
83	0	0	0	0	3	3
84	0	0	0	0	11	11
85	0	2	0	0	0	2
88	0	2	2	0	10	14
Total	**0**	**10**	**17**	**0**	**121**	**148**

[a] No sources were measured under Category IV requirements; sources potentially having a dose impact between 1.0×10^{-2} and 1.0×10^{-3} mrem/y (1.0×10^{-4} and 1.0×10^{-5} mSv/y) were measured using the more rigorous Category III requirements.

All Berkeley Lab release points that were operational in 2003 were minor sources of radionuclides; that is, the effective dose equivalent from each release point was less than 0.1 mrem/y (1.0×10^{-3} mSv/y), the threshold limit for Category I measurements. Minor release points (Category II-IV) were continuously sampled with weekly or monthly analysis of the samples. As shown in Table 3, all Category IV release points were measured using the more rigorous Category III requirements.

To determine the annual dose from airborne emissions, the full set of authorized radionuclides was reviewed, and a subset was developed that includes radionuclides that were potentially used (received or measured) in 2003 (Table 4).

Table 4 Radionuclides Potentially Used (Received or Measured) In 2003

Element	Atomic number	Radionuclide	Principal radiation types	Energy (MeV)	Half-Life
Americium	95	^{241}Am	alpha	5.41	432.7 years
				5.44	
			gamma	0.060	
		^{243}Am	alpha	5.276	7370 years
				5.234	
			gamma	0.075	
Antimony	51	^{122}Sb	beta	1.98	2.7 days
			positron	0.57	
			gamma	0.654	
		^{124}Sb	beta	2.301	60.2 days
			gamma	0.603	
		^{125}Sb	beta	0.302	2.8 years
			gamma	0.428	
				0.601	
Barium	56	^{133}Ba	gamma	0.356	10.5 years
				0.081	
Beryllium	4	^{7}Be	gamma	0.478	53.3 days
Bismuth	83	^{207}Bi	gamma	0.570	32 years
Calcium	20	^{45}Ca	beta	0.258	162.7 days
Californium	98	^{249}Cf	alpha	5.813	351 years
			gamma	0.388	
		^{252}Cf	alpha	6.12	2.6 years
Carbon	6	^{11}C	positron	0.960	20.4 minutes
		^{14}C	beta	0.157	5715 years
Cerium	58	^{141}Ce	beta	0.436	32.5 days
				0.581	
			gamma	0.145	
		^{144}Ce[a]	beta	0.318	284.6 days
Cesium	55	^{134}Cs	beta	0.658	2.1 years
			gamma	0.605	
				0.796	
				1.038	
				1.168	
				1.365	

Table 4 Radionuclides Potentially Used (Received or Measured) In 2003 (continued)

Element	Atomic number	Radionuclide	Principal radiation types	Energy (MeV)	Half-Life
Cesium	55	^{137}Cs[a]	beta	0.514	30.1 years
			gamma	0.662	
Cobalt	27	^{57}Co	gamma	0.122	271.8 days
		^{60}Co	beta	0.318	5.3 years
			gamma	1.333	
				1.173	
Curium	96	^{243}Cm	alpha	5.785	29.1 years
			gamma	0.278	
				0.228	
				5.805	
		^{244}Cm	alpha	5.763	18.1 years
Europium	63	^{152}Eu	beta	0.699	13.5 years
			gamma	0.122	
				0.344	
				1.408	
Fluorine	9	^{18}F	positron	0.635	1.8 hours
Gold	79	^{198}Au	beta	0.961	2.7 days
			gamma	0.412	
Hafnium	72	^{175}Hf	gamma	0.343	70 days
Holmium	67	^{166m}Ho	beta	0.065	1200 years
			gamma	0.184	
				0.712	
				0.810	
Hydrogen (Tritium)	1	^{3}H	beta	0.0186	12.3 years
Iodine	53	^{123}I	gamma	0.159	13.2 hours
		^{125}I	gamma	0.035	59.4 days
		^{131}I	beta	0.606	8.0 days
			gamma	0.364	
Iron	26	^{55}Fe	x-rays	0.108	2.73 years
		^{59}Fe	beta	0.466	44.5 days
			gamma	1.099	
				1.292	
Manganese	25	^{54}Mn	gamma	0.835	312.1 days
Neptunium	93	^{237}Np	alpha	4.78	2.1×10^{6} years
			gamma	0.030	
				0.087	
		^{239}Np	beta	0.341	2.4 days
				0.438	
			gamma	0.106	
				0.228	
				0.278	
Nickel	28	^{63}Ni	beta	0.067	101 years
Niobium	41	^{95}Nb	beta	0.160	35.0 days
			gamma	0.765	
Nitrogen	7	^{13}N	positron	1.190	10.0 minutes
Oxygen	8	^{15}O	positron	1.72	122 seconds

Table 4 Radionuclides Potentially Used (Received or Measured) In 2003 (continued)

Element	Atomic number	Radionuclide	Principal radiation types	Energy (MeV)	Half-Life
Phosphorus	15	^{32}P	beta	1.71	14.3 days
		^{33}P	beta	0.25	25.3 days
Plutonium	94	^{238}Pu	alpha	5.50 5.46	87.7 years
		^{239}Pu	alpha	5.156 5.144 5.105	24,100 years
Protactinium	91	^{233}Pa	beta	0.256	27 days
			gamma	0.312	
Radium	88	^{226}Ra[a]	alpha	4.784 4.602	1599 years
			gamma	0.186	
		^{228}Ra[a]	beta	0.039 0.015 0.026	5.8 years
Rhodium	45	^{101}Rh	gamma	0.307	4.4 days
Rubidium	37	^{86}Rb	beta	1.77	18.7 days
			gamma	1.08	
Ruthenium	44	^{106}Ru[a]	beta	0.039	1.0 year
Scandium	21	^{46}Sc	beta	0.357	83.8 days
			gamma	1.121 0.889	
Sodium	11	^{22}Na	positron	0.546	2.6 years
			gamma	1.275	
Strontium	38	^{89}Sr	beta	1.488	50.5 days
		^{90}Sr[a]	beta	0.546	28.8 years
Sulfur	16	^{35}S	beta	0.167	87.2 days
Tantalum	73	^{182}Ta	beta	0.522 0.25	114.4 days
			gamma	0.068 1.121	
Technetium	43	^{99}Tc	beta	0.294	213,000 years
		^{99m}Tc	gamma	0.141	6.0 hours
Thallium	81	^{201}Tl	gamma	0.167	3.0 days
		^{204}Tl	beta	0.763	3.8 years
Thorium	90	^{229}Th	alpha	4.845 4.901 4.814	7300 years
			gamma	0.194 0.086 0.211	
		^{230}Th[a]	alpha	4.688 4.621	75,400 years
			gamma	0.068	
		^{232}Th[a]	alpha	4.012 3.947	1.4×10^{10} years

Table 4 Radionuclides Potentially Used (Received or Measured) In 2003 (continued)

Element	Atomic number	Radionuclide	Principal radiation types	Energy (MeV)	Half-Life
Thulium	69	^{170}Tm	beta	0.968	128.6 days
				0.883	
			gamma	0.084	
Uranium	92	^{232}U	alpha	5.320	69.8 years
				5.264	
		^{233}U	alpha	4.824	159,200 years
				4.783	
		^{234}U	alpha	4.776	246,000 years
				4.725	
			gamma	0.053	
				0.121	
		^{235}U	alpha	4.398	7.0×10^8 years
				4.366	
			gamma	0.144	
				0.186	
		^{238}U[a]	alpha	4.197	4.5×10^9 years
				4.147	
Xenon	54	^{133}Xe	beta	0.346	5.2 days
			gamma	0.081	
Yttrium	39	^{90}Y	beta	2.281	2.67 days
Zinc	30	^{65}Zn	gamma	1.116	243.8 days
Zirconium	40	^{88}Zr	gamma	0.393	83.4 days
		^{95}Zr[a]	beta	0.368	64.0 days
				0.400	
			gamma	0.724	
				0.757	

[a] Includes progeny

As discussed above, release points in categories II through IV were sampled or monitored, in accordance with Berkeley Lab's *Quality Assurance Project Plan for Radionuclide NESHAP*. At continuously sampled sites, a representative sample of the exhaust air passes through the appropriate collection medium (silica gel for tritium, sodium hydroxide solution for ^{14}C, activated carbon for ^{125}I, and fiberglass filter for particulate alpha- and beta-emitting radionuclides). Each medium is replaced either weekly or monthly, depending on the measurement category. The radionuclides collected on the media are analyzed either at a commercial laboratory (for tritium) or an on-site laboratory (for all other radionuclides). At sites continuously monitored in real time, a sample of the exhaust air is passed through or over detectors that provide a nearly instantaneous measurement of positron-emitting radionuclides (at Buildings 56 and 88), alpha-emitting radionuclides (at Building 70A), or tritium (at Building 75 until June 2003, when real-time monitoring was discontinued [see Section 1.3.10]).

Release points in Category V were, in general, not sampled or monitored. Instead, Berkeley Lab evaluated the effective dose equivalent from Category V release points by assuming that all radionuclides received during the year were completely used at Category V release points. The

amount of each radionuclide emitted was determined by multiplying the entire quantity of that radionuclide received during the year by the appropriate EPA-specified release factor based on the radionuclide's physical state (provided in 40 CFR Part 61, Appendix D). This method provides a conservative, upper-bound estimate of the annual emissions. In fact, for most sources comprising a mixture of Category II–V release points, emissions are overestimated because they are quantified by adding the calculated emission of received radionuclides (as described above) to the amount measured by sampling or monitoring the exhaust stack.

The total number of Category V release points is based on the number of areas where radionuclide use was authorized. All radioactive material areas were included, regardless of whether radionuclides were actually used there during the year. This method also provides a conservative, upper-bound estimate of the impact of radioactive airborne emissions.

To estimate effective dose equivalent, CAP88-PC, Version 2, provides a library of 265 radionuclides; however, this library does not include all of the radionuclides potentially used at Berkeley Lab. For radionuclides not included in the library, EPA has approved the interim use of surrogates at Berkeley Lab. Berkeley Lab selects a surrogate radionuclide that is similar to the actual radionuclide in its metabolic behavior, mode of decay, and decay energy. Note that for surrogates used to represent radionuclides not included in the CAP88-PC library, the dose contribution to the site-wide MEI is very low: in 2003, the dose from all surrogates taken together is about 6×10^{-3} % of the total dose from all radionuclides.

In addition, Berkeley Lab conservatively assigns the high-risk alpha-emitting radionuclide, ^{232}Th, and the high-risk beta-emitting radionuclide, ^{90}Sr, as surrogates for gross alpha and gross beta measurements, respectively. To verify this assumption, in 2003 the Berkeley Lab Low Background Facility used gamma spectroscopy to analyze particulate samples collected on fiberglass filter and identify the radionuclides responsible for gross alpha and gross beta measurements. The results of gamma spectroscopy indicate that the radionuclides represented by gross alpha and gross beta measurements are actually lower-risk radionuclides such as ^{249}Cf, ^{40}K, and daughters of ^{238}U (^{210}Pb) and ^{235}U (^{231}Pa). Thus, it was confirmed that the use of the higher-risk radionuclides ^{232}Th and ^{90}Sr provides an upper-bound estimate of the effective dose equivalent.

Furthermore, all tritium releases are assumed to be in the form of tritiated water because CAP88-PC cannot calculate doses from releases of tritiated hydrogen gas. CAP88-PC treats all tritium gas releases as tritiated water, which overestimates the dose from inhalation by a factor of 10,000 (ICRP 1996).

In estimating effective dose equivalent from Category II–IV release points, the actual measured sample activities were used to calculate an annual total, in accordance with DOE guidance (DOE 1991), even when the individual sample activity was less than the analytical laboratory's minimum

detectable activity. Of the radionuclides listed in Table 4, three radionuclides account for nearly all (more than 99.9%) of the activity emitted in 2003: fluorine-18 (^{18}F), carbon-11 (^{11}C), and hydrogen-3 (tritium or ^{3}H).

Following DOE guidance (DOE 1993), many Berkeley Lab release points were grouped using the following criteria:

- The sum of the effective dose equivalent attributable to all release points in the group must be less than 0.1 mrem (1×10^{-3} mSv).
- Release points must be in close proximity (in the same or a nearby building), with similar operations and similar nuclides used in the facilities.
- Critical receptors must be the same.

Using this grouping scheme, Berkeley Lab identified 12 NESHAP point sources (buildings with stacks or vents) and group sources (two or more point sources) (Table 5). In 2003, no area sources (emissions sources that are not clearly delimited and are not point or group sources) were identified.

For each source, Berkeley Lab used the EPA-approved atmospheric dispersion dose calculation computer code CAP88-PC, Version 2, to estimate the effective dose equivalent to the member of the public nearest to the source (the local MEI) and to the member of the public who could receive the greatest dose from all Berkeley Lab radioactive air emissions (the site-wide MEI). The location of the site-wide MEI is a hypothetical person residing at the UC Lawrence Hall of Science, 460 m east of Building 56 (the source of greatest emissions in 2003). The CAP88-PC computer model assessments were performed separately to simulate six point sources and six group sources.

As identified in Figure 1, Buildings 1 and 3 are located outside of Berkeley Lab's main perimeter and could be considered separate facilities since they are not on one contiguous site. However, Buildings

Table 5 NESHAP Point and Group Sources In 2003

NESHAP Source	Type of source	Location
Building 1	Point	UC Berkeley Campus
Building 3	Point	UC Berkeley Campus
Building 6 and 16	Group	Main Site
Buildings 26 and 76	Group	Main Site
Buildings 55, 56, and 64	Group	Main Site
Buildings 70 and 70A	Group	Main Site
Building 71	Point	Main Site
Building 72	Point	Main Site
Buildings 74, 83, and 84	Group	Main Site
Building 75 and 75A	Group	Main Site
Building 85	Point	Main Site
Building 88	Point	Main Site

1 and 3 are located on the adjacent UC Berkeley campus and are within walking distance of the main Berkeley Lab site. Annual radioactive air emissions from these off-site buildings and the associated effective dose equivalent at each local MEI are much less than the highest building emissions and doses at the main Berkeley Lab site. Thus, it would be inappropriate and misleading to model and report these much lower doses separately. Therefore, for reporting and dose-modeling purposes, all of these off-site buildings are considered as being on one contiguous Berkeley Lab site.

1.3.1 Building 1 (Donner Laboratory)

Scientists at Donner Laboratory conduct research in nuclear medicine through the use of new chemical probes and new instrumentation for applications to aging, atherosclerosis, and cancer. The building is located at the eastern edge of the UC Berkeley campus. The predominant radionuclides used are ^{14}C, ^{3}H, ^{125}I, ^{32}P, and ^{35}S as labeled amino acids and DNA precursors. Many UC Berkeley campus employees share this building for various other research activities. Work is mostly done on bench tops and in hoods. Emissions are from building vents and hoods.

In 2003, most release points at Building 1 were classified as Category V, for which the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments. Two stacks in Building 1 were sampled and analyzed monthly for ^{125}I, ^{14}C, gross alpha, gross beta, and tritium. To estimate the dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 6.

Table 6 Building 1 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
18	10	ESE	UC Berkeley	C-14	1.1E-04	4.0E-07	2.9
				H-3	5.6E-05	7.7E-09	0.1
				I-125	3.1E-07	1.8E-07	1.3
				P-32	1.9E-05	2.3E-07	1.7
				S-35	1.5E-05	5.4E-08	0.4
				Gross alpha (Th-232)	6.3E-08	1.3E-05	91.1
				Gross beta (Sr-90)	3.7E-07	3.3E-07	2.4
					Total	**1.4E-05**	**100%**

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv

1.3.2 Building 3 (Calvin Laboratory)

The Calvin Laboratory conducts basic research on the dynamics of living cells and on the interaction of radiant energy with organic matter. The laboratory has made significant contributions to our understanding of the molecular mechanisms of photosynthesis and of the effects of environmental pollutants on plant and animal cells. As with Building 1, this building is located in the eastern portion of the UC Berkeley campus. The predominant radionuclides used are ^{32}P, ^{33}P, and ^{35}S as labeled amino acids and DNA precursors; ^{14}C and ^{3}H are also used in small quantities. Building 3 is occupied by Berkeley Lab and UC Berkeley personnel. Work is done on bench tops and in hoods. Emissions are from building vents and hoods.

In 2003, all release points in Building 3 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments. No sampling or monitoring was required. For dose calculations, ^{32}P was used as a surrogate for ^{33}P, which is not included in the CAP88-PC library, because they have similar metabolic and radiological properties. This surrogate contributed less than 2×10^{-3} % of the total dose to the site-wide MEI. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 7.

Table 7 Building 3 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI descrip-tion	Radio-nuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
15	30	S	UC Berkeley	C-14	1.0E-07	3.7E-09	0.9
				H-3	1.0E-06	1.4E-09	0.3
				P-32	1.5E-06	1.4E-07	34.9
				P-33 (P-32)	2.0E-06	1.9E-07	46.5
				S-35	3.0E-06	7.1E-08	17.4
					Total	**4.1E-07**	**100%**

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv

1.3.3 Buildings 6 and 16 (Advanced Light Source and Accelerator and Fusion Research)

The Advanced Light Source (ALS) in Building 6 is one of the world's brightest synchrotron radiation sources, producing light in the extreme ultraviolet and soft x-ray regions of the spectrum. The ALS is a national user facility open to qualified scientists and engineers, in a broad range of disciplines, from national laboratories, private industry, and universities.

The ALS synchrotron accelerates electrons to 1.5 GeV, and the storage ring maintains a normal operating beam current of 400 mA at an energy between 1 and 2 GeV. The ALS produces neutrons during its operation, which activate the components of air in the injector vault. Because the ALS is a

low-power accelerator, compared to Berkeley Lab's other accelerators such as the 88-Inch Cyclotron, its generation of air activation products is substantially lower. The maximum annual emissions of ^{13}N and ^{15}O (the most significant air activation products) are calculated to be 1.8×10^{-5} Ci (6.5×10^{5} Bq) and 9.4×10^{-8} Ci (3.5×10^{3} Bq), respectively, based on an optimally thick aluminum target with a 1.5-GeV incident electron beam. These are conservative estimates that have not been exceeded since their original determination (Donahue 1991).

At the ALS, the beam is under ultra-high vacuum within the beam enclosure. The beam enclosure is ventilated by an exhaust system to a roof stack. These stacks are not sampled or monitored because Building 6 release points are classified as Category V, and no special effluent capture or recovery systems are required for the ALS emissions.

In Building 16, research is conducted on the use of prompt gamma analysis to characterize the chemical composition of unknown materials. This project is authorized to use microcurie to millicurie quantities of uranium to calibrate equipment, although no uranium was received for use in 2003. In 2003, the release point in Building 16 was classified as Category V: no sampling or monitoring was required.

The radionuclide inventory at Buildings 6 and 16 was controlled by radiation work authorizations and permits and by periodic assessments. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 8.

Table 8 Building 6 and 16 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radio-nuclide (surrogate)	Annual emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of total dose (%)
9	370	NNE	UC Lawrence Hall of Science	N-13	1.8E-05	1.3E-08	99.6
				O-15	9.4E-08	5.5E-11	0.4
					Total	**1.3E-08**	**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Includes progeny

1.3.4 Buildings 26 and 76 (Radioanalytical Laboratories)

In these buildings, low-activity radiochemical analyses of bioassay samples, work-place and environmental samples, and hazardous waste are performed by Berkeley Lab. In addition, Building 76 has some detector calibration sources. Trace quantities of radionuclides are used in sample spiking and standards preparation. Emissions are from building vents and hood exhaust stacks.

In 2003, release points within Buildings 26 and 76 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic

assessments. No sampling or monitoring was required. Because all radioactive samples analyzed during the year were sent to the Hazardous Waste Handling Facility after analysis, the annual emissions were conservatively estimated as the amount sent as waste multiplied by the appropriate EPA-specified physical state emission factor (provided in 40 CFR Part 61, Appendix D). For dose calculations, ^{245}Cm was used as a surrogate for ^{249}Cf, which is not included in the CAP88-PC library, because they have similar metabolic and radiological properties. This surrogate contributed about 1×10^{-6} % of the total dose to the site-wide MEI. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 9.

Table 9 Building 26/76 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
8	250	N	UC Lawrence Hall of Science	Am-241	1.3E-12	2.7E-09	0.3
				Am-243	1.6E-13	3.4E-10	< 0.1
				Ba-133	1.3E-12	1.0E-11	< 0.1
				Be-7	1.3E-15	2.6E-17	< 0.1
				C-14	2.3E-09	4.7E-11	< 0.1
				Ce-144[e]	1.3E-14	2.2E-14	< 0.1
				Cf-249 (Cm-245)	5.2E-14	1.1E-10	< 0.1
				Cm-243	1.3E-13	1.8E-10	< 0.1
				Cm-244	1.1E-14	1.2E-11	< 0.1
				Co-57	8.7E-15	2.4E-15	< 0.1
				Co-60	1.8E-11	4.4E-10	0.1
				Cs-134	4.0E-12	3.2E-11	< 0.1
				Cs-137[e]	4.8E-09	1.1E-07	12.5
				Fe-55	2.0E-15	2.4E-17	< 0.1
				H-3	5.6E-08	4.8E-11	< 0.1
				I-125	1.0E-09	3.1E-09	0.4
				I-131	1.0E-09	1.1E-09	0.1
				Mn-54	1.4E-14	2.4E-14	< 0.1
				Nb-95	4.3E-15	1.0E-15	< 0.1
				Ni-63	1.4E-15	2.1E-17	< 0.1
				Np-237	4.1E-12	7.7E-09	0.9
				Np-239	1.4E-13	1.9E-15	< 0.1
				Pu-238	3.1E-15	3.8E-12	< 0.1
				Pu-239	1.1E-12	1.5E-09	0.2
				Ra-226[e]	1.0E-14	1.7E-10	< 0.1
				Ra-228[e]	4.5E-10	5.2E-07	60.4
				Ru-106[e]	6.0E-17	1.5E-16	< 0.1
				S-35	1.0E-14	9.2E-17	< 0.1
				Sb-125	1.9E-15	5.1E-15	< 0.1
				Sr-89	1.8E-12	1.0E-13	< 0.1
				Sr-90[e]	6.2E-11	2.0E-10	< 0.1
				Th-230[e]	1.3E-12	1.6E-09	0.2
				Th-232[e]	1.5E-12	3.7E-09	0.4

Table 9 Building 26/76 Source Characteristics and Dose Impacts (continued)

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI descrip-tion	Radio-nuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
				U-232	1.0E-10	1.9E-07	21.5
				U-235	5.3E-15	2.6E-12	< 0.1
				U-238[e]	1.1E-11	2.4E-08	2.8
				Zn-65	3.2E-12	4.1E-12	< 0.1
					Total	**8.6E-07**	**100%**

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv
[e] Includes progeny

1.3.5 Buildings 55, 56, and 64 (Center for Functional Imaging, Biomedical Isotope Facility, and Life Sciences Research)

In Building 56, researchers at the Biomedical Isotope Facility develop radiopharmaceuticals and advanced medical imaging technologies, including positron emission tomography (PET), single photon emission computed tomography (SPECT), and nuclear magnetic resonance imaging (MRI). Researchers apply these technologies to the study of heart disease, aging, neurological and psychiatric diseases, and cancer. Building 56 houses a small cyclotron to support such studies.

The Building 56 cyclotron accelerates protons to 11 MeV, with a normal operating beam current of 50 μA. The cyclotron produces ^{18}F, ^{11}C, ^{13}N, and ^{15}O for positron emission tomography and other experimental studies. In addition, in collaboration with the 88-Inch Cyclotron, the Building 56 cyclotron produces ^{11}C, ^{14}O, ^{15}O, ^{13}N, ^{17}F, and ^{18}F for the Berkeley Experiments with Accelerated Radioactive Species (BEARS) Project. All the potentially airborne radionuclides produced at Building 56 are positron emitters.

At the Building 56 cyclotron, the entire beam path is enclosed within shielding, and the enclosure is ventilated by an exhaust system to a roof stack. All emissions from the cyclotron enclosure are through the roof stack, which is monitored by a real-time positron detector. No special effluent capture or recovery systems are required for the cyclotron emissions.

A second stack at Building 56 is also continuously monitored for positron-emitting radionuclides using real-time radiation detectors. This stack exhausts air from lead-shielded glove boxes in Room 56-100, adjacent to the cyclotron enclosure, where positron-emitting radionuclides produced in the cyclotron are handled.

The Building 56 cyclotron's safety systems (monitoring, filtration, isolation, safety interlocks, and ventilation) were designed to ensure that the facility has a negligible impact on the surrounding

environment. In 1995, a Berkeley Lab safety analysis determined that the facility is designed and operated to maintain exposures to the public and the environment as low as reasonably achievable.

For dose calculations, all positron-emitting radionuclides measured in effluent from the Building 56 stacks are assumed to be ^{18}F. Fluorine-18 is an appropriate surrogate for radioisotopes of carbon, nitrogen, and oxygen because it has metabolic and radiological properties that are similar to the other radionuclides. In 2003, ^{18}F emitted from Building 56 stacks accounted for about 73% of the dose to the site-wide MEI. The location of this hypothetical person is the UC Lawrence Hall of Science, 460 m east of Building 56, even though a closer, local MEI is located 250 m north-northwest of Building 56. This is due to prevailing wind directions (from the west and west-northwest) that tend to carry airborne emissions toward the UC Lawrence Hall of Science.

Annual ^{18}F emissions from Building 56 stacks are believed to be overestimated because false-positive results occur when ^{18}F absorbs onto the real-time detectors, causing over-measurement and calculated doses that are not correlated with laboratory activities. These false positive measurements are included in the calculation of annual ^{18}F emissions. In 2003, efforts to improve our understanding of these false positive measurements began; those efforts will continue in 2004.

At Building 55, the primary radiological activities carried out by life sciences researchers are positron emission tomography using ^{18}F (produced at the Building 56 cyclotron) and metabolic studies using ^{125}I. Other projects include a gene therapy study, work with ^{32}P to determine the metabolic fate of DNA-based imaging agents, and evaluation of cardiac kinetics using various radioactive tracers (such as ^{99m}Tc and ^{201}Tl). Work with radioactive iodine is done in a fume hood that is fitted with a high-efficiency particulate air (HEPA) filter and a tetraethylene diamine (TEDA)-doped carbon filter.

In 2003, ^{201}Tl was among the radionuclides received for use at Building 55, but it is not included in the CAP88-PC library. To model the dose from this radionuclide, the surrogate ^{67}Ga was used. This surrogate is appropriate because it has similar metabolic and radiological properties to the received radionuclide. This surrogate contributed less than 2×10^{-5} % of the total dose to the site-wide MEI. In 2003, one stack on Building 55 was sampled and analyzed monthly for ^{125}I, gross alpha, and gross beta. To estimate the dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively.

In Building 64, life sciences researchers use ^{32}P to label probes for DNA analysis. In 2003, the release point in Building 64 was classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 10.

Table 10 Building 55/56/64 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI descrip-tion	Radio-nuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
16	250	NNW	Residence	C-14	3.5E-07	5.0E-09	< 0.1
				H-3	1.8E-06	8.7E-10	< 0.1
				I-123	1.0E-04	6.0E-07	< 0.1
				I-125	3.0E-04	6.5E-04	9.7
				I-131	1.0E-05	7.1E-06	0.1
				P-32	2.5E-07	8.4E-09	< 0.1
				Tc-99m	1.8E-04	6.6E-08	< 0.1
				Tl-201 (Ga-67)	4.0E-07	1.4E-09	< 0.1
				Positron (F-18)	3.6E+00	6.0E-03	90.2
				Gross alpha (Th-232)	5.8E-09	4.2E-06	0.1
				Gross beta (Sr-90)	1.2E-07	2.8E-07	< 0.1
					Total	**6.7E-03**	**100%**

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv
[e] Includes progeny

1.3.6 Buildings 70 and 70A (Nuclear, Chemical, Life, and Earth Sciences and Environmental Energy Technology)

Nuclear Sciences Division programs include research in nuclear structure and reactions, relativistic nuclear collisions, nuclear and particle astrophysics, nuclear data evaluation, and nuclear theory. Chemical Sciences Division conducts research in the areas of chemical physics and the dynamics of chemical reactions, the structure and reactivity of transient species, electron spectroscopy, surface chemistry and catalysis, electrochemistry, chemistry of the actinide elements and their relationship to environmental and physiological issues, and atomic physics. Life Sciences Division programs include studies of tumor cells, DNA damage from radiation, and impacts of cosmic radiation exposure to astronauts. Earth Sciences Division and Environmental Energy Technology programs perform fundamental and applied research related to energy and environmental resources.

Programs carried out in these facilities include super-heavy nuclear studies, waste migration research using tracer amounts of radionuclides, nuclear chemistry experiments, analysis of activated geological samples, and radiation biology research. Research activities using radioactive material are carried out by various research groups in the many small laboratories within Buildings 70 and 70A.

In 2003, 32 release points in Buildings 70 and 70A were classified as Category V and an additional 11 release points were sampled continuously and analyzed weekly (Category II) or monthly

(Category III and IV). In addition to being continuously sampled, one stack on Building 70A was monitored for alpha-emitting radionuclides with a real-time, continuous air monitor. For this stack, the greatest measured results were from the continuous sampling system, and these results were used to determine emissions from the stack. Sampled radionuclides include ^{125}I, ^{14}C, gross alpha, gross beta, and tritium.

In addition to sampled emissions, radionuclides received for use at all Category II-V release points during the year are typically assumed to be emitted. In 2003, however, legacy material stored in the Heavy Elements Research Laboratory (HERL) in Building 70A was inventoried and entered into the receipts database. Only small amounts of legacy material were actually used in 2003, and most of this work was performed under HERL's primary work authorization in laboratories exhausted by sampled or monitored stacks. Nonetheless, some legacy material may have been used under this authorization in Building 70A laboratories that are not exhausted by sampled or monitored stacks (Category V release points). To determine emissions from such release points, the principal investigator responsible for the work provided an estimate of actual quantities of radionuclides used in Category V release points under HERL's primary work authorization during the year. These values were multiplied by the appropriate EPA-specified physical state emission factor and then added to the actual measured emissions. This approach provided a conservative estimate of emissions from Building 70A.

In 2003, ^{207}Bi, ^{45}Ca, ^{249}Cf, ^{175}Hf, ^{101}Rh, ^{182}Ta, ^{204}Tl, ^{170}Tm, and ^{88}Zr were among the radionuclides measured or received for use at Buildings 70 and 70A, but they are not included in the CAP88-PC library. To model the dose from these radionuclides, the surrogates ^{181}Hf, ^{90}Sr, ^{245}Cm, ^{210}Pb, ^{93}Mo, ^{181}Hf, ^{214}Pb, ^{181}Hf, and ^{110m}Ag, respectively, were used. The surrogates are appropriate because they have similar metabolic and radiological properties to the received radionuclides. These surrogates contributed less than 4×10^{-3} % of the total dose to the site-wide MEI.

To estimate dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 11.

Table 11 Building 70/70A Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
16	270	WSW	UC Berkeley dormitory	Am-241	5.0E-09	1.1E-06	0.3
				Am-243	1.0E-07	2.2E-05	5.7
				Bi-207 (Hf-181)	5.0E-09	1.3E-10	< 0.1
				C-14	8.8E-05	2.6E-07	0.1
				Ca-45 (Sr-90)	1.3E-10	6.5E-11	< 0.1

Table 11 Building 70/70A Source Characteristics and Dose Impacts (continued)

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
16	270	WSW	UC Berkeley dormitory	Ce-141	2.8E-11	2.0E-13	< 0.1
				Cf-249 (Cm-245)	5.0E-10	1.1E-07	< 0.1
				Cf-252	5.0E-12	3.1E-10	< 0.1
				Cm-244	1.4E-11	1.6E-09	< 0.1
				Cm-248	7.1E-11	6.0E-08	< 0.1
				Co-60	4.7E-11	1.4E-10	< 0.1
				Cs-134	2.1E-11	2.2E-11	< 0.1
				Eu-152	5.0E-09	1.6E-08	< 0.1
				Fe-59	2.5E-09	1.2E-10	< 0.1
				H-3	1.3E-05	1.3E-09	< 0.1
				Ho-166m	4.0E-09	5.5E-08	< 0.1
				I-125	2.3E-08	1.0E-08	< 0.1
				Mn-54	1.0E-10	2.1E-11	< 0.1
				Na-22	1.0E-09	1.5E-09	< 0.1
				Np-237	1.1E-06	2.3E-04	57.7
				P-32	1.6E-06	1.1E-08	< 0.1
				Pa-233	4.0E-11	4.2E-13	< 0.1
				Pu-238	2.9E-08	3.7E-06	1.0
				Pu-239	4.6E-09	6.5E-07	0.2
				Ra-226[e]	1.0E-09	2.0E-08	< 0.1
				Rb-86	8.4E-12	8.4E-14	< 0.1
				Rh-101 (Mo-93)	5.0E-11	2.4E-12	< 0.1
				Sc-46	7.0E-10	1.0E-10	< 0.1
				Sr-90[e]	4.0E-09	2.0E-09	< 0.1
				Ta-182 (Hf-181)	1.0E-09	2.7E-11	< 0.1
				Tc-99	1.1E-06	8.2E-08	< 0.1
				Th-229	1.4E-08	4.0E-06	1.0
				Th-232[e]	1.3E-08	3.4E-06	0.9
				Tl-204 (Pb-214)	1.0E-09	4.4E-13	< 0.1
				Tm-170 (Hf-181)	1.0E-08	2.7E-10	< 0.1
				U-233	1.7E-07	9.3E-06	2.4
				U-234	4.8E-10	2.6E-08	< 0.1
				U-235	8.1E-10	4.2E-08	< 0.1
				Y-90	8.0E-09	3.1E-11	< 0.1
				Zr-88 (Ag-110m)	3.0E-10	1.7E-10	< 0.1
				Zr-95[e]	5.0E-07	5.8E-08	< 0.1

Table 11 Building 70/70A Source Characteristics and Dose Impacts (continued)

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
16	270	WSW	UC Berkeley dormitory	Gross alpha (Th-232)	5.4E-07	7.8E-05	20.0
				Gross beta (Sr-90)	2.6E-06	1.3E-06	0.3
				U-238[e]	1.7E-07	4.0E-05	10.4
				Hf-175 (Pb-210)	5.6E-09	6.0E-08	< 0.1
				Total	**3.9E-04**	**100%**	

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv
[e] Includes progeny

1.3.7 Building 71 (Accelerator and Fusion Research)

Building 71 formerly housed the Heavy Ion Linear Accelerator (HILAC), which is no longer in operation. In 2003, the Laser Optics and Accelerator Systems Integrated Studies (l'OASIS) Group used the building for a low-voltage, laser-driven accelerator. This small accelerator operates at voltages too low to produce air activation products; however, in 2003 the accelerator was authorized to produce solid ^{18}F on targets for use at other facilities. The release points in Building 71 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 12.

Table 12 Building 71 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)	Annual emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of total dose (%)
13	190	NNW	Residence	F-18	6.0E-13	1.3E-15	100
				Total	**1.3E-15**	**100%**	

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.8 Building 72 (Low-Background Facility)

The Low-Background Facility in Building 72 is used to perform gamma spectroscopy to characterize low-level radioactive material in support of low-activity materials certification; studies in cosmic ray and neutron activation; nuclear science experiments; and environment, safety, and health activities. In 2003, ^{198}Au and ^{122}Sb were among the radionuclides received for use at Building 72, but they are not included in the CAP88-PC library. To model the dose from these radionuclides, the surrogates

^{192}Ir and ^{99}Mo, respectively, were used. These surrogates contributed about 3×10^{-8} % of the total dose to the site-wide MEI. The surrogates are appropriate because they have similar metabolic and radiological properties to the received radionuclides.

In 2003, release points in Building 72 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments. A summary of the CAP88-PC source term input parameters and effective dose equivalent for this source is presented in Table 13.

Table 13 Building 72 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
3	230	SSW	UC Berkeley	Au-198 (Ir-192)	3.0E-12	2.9E-12	99.8
				Sb-122 (Mo-99)	6.0E-16	2.4E-17	< 0.1
				Sb-124	2.0E-15	2.9E-15	0.1
				Xe-133	8.0E-15	1.3E-18	< 0.1
				Zn-65	7.0E-16	1.5E-15	0.1
					Total	**2.9E-12**	**100%**

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv

1.3.9 Buildings 74, 83, and 84 (Human Genome Facility and Life Sciences)

Research in these buildings includes a wide variety of cell biology, virology, research medicine, and genomics projects. The Human Genome Center of Berkeley Lab is oriented primarily toward developing and implementing methods for cost-effective and accurate high-throughput human DNA sequencing. Emissions from Building 74 come from stacks that vent hoods and individual workplaces. Buildings 83 and 84 vent through HEPA-filtered biological cabinets. When research activities involve ^{125}I, they are normally carried out in TEDA-doped activated-carbon-filtered enclosures; however, no radioactive iodine was received in 2003.

In 2003, release points in Buildings 74, 83, and 84 were classified as Category V, and the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments. No sampling or monitoring was required. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 14.

Table 14 Buildings 74/83/84 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radio-nuclide (surrogate)	Annual emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of total dose (%)
7	160	SSE	UC Berkeley	C-14	1.0E-07	9.5E-09	< 0.1
				H-3	5.0E-06	2.0E-08	< 0.1
				P-32	2.0E-04	4.2E-05	100.0
				S-35	2.5E-06	1.0E-07	0.2
				Total	**4.2E-05**	**100%**	

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.10 Buildings 75 and 75A (Former National Tritium Labeling Facility and Storage)

The National Tritium Labeling Facility (NTLF) was a national resource center funded by the National Institutes of Health and engaged in tritium-labeling research and development. The facility was mainly used for activities in which a wide variety of molecules were labeled with tritium and purified for further use in chemical, biochemical, and radiopharmaceutical studies. In fall 2001, the National Institutes of Health cancelled its funding of the NTLF. The facility ceased labeling operations in December 2001 and eliminated 90% of its tritium inventory by sending it to another DOE facility. By the end of 2002, closure activities that included removal of radioactive material, dismantling and disposition of equipment, and decontamination and decommissioning of the laboratories, outdoor facilities, and ancillary spaces were complete.

In the past, the NTLF was the only source at Berkeley Lab that historically resulted in more than 1% of the NESHAP effective dose equivalent standard of 10 mrem/y. By the end of 2002, emissions had decreased by more than two orders of magnitude and the facility met Category III measurement criteria.

There are two stacks associated with NTLF activities: one on the northern hillside near Building 75 and one on the roof of Building 75. In 2003, continuous sampling with subsequent laboratory analysis was performed on both stacks.

At the hillside stack, in addition to continuous sampling, real-time monitoring was performed continuously until June 2003. At this point, tritium emissions from the stack had decreased to well below the detection sensitivity of the real-time monitoring system. In June, the EPA confirmed that real-time monitoring of the hillside stack was not required (Attachment A) and Berkeley Lab discontinued this monitoring, although continuous sampling and weekly or monthly analysis for tritium continued.

In November 2003, the sampling location for the hillside stack was moved to a location nearer the stack exit to allow for more accurate measurement of the small amount of residual tritium in the duct. The residual tritium emissions are estimated to be less than 18 mCi/year, an amount so small that it does not significantly increase the calculated dose to the site-wide MEI. Nonetheless, the hillside sampling location allows more accurate measurement of current emissions, which are primarily due to residual tritium in the building and exhaust ducts.

Other release points in Building 75 were not associated with the National Tritium Labeling Facility but with the former Hazardous Waste Handling Facility, which moved to its present location in Building 85 in 1997. These include Building 75, Room 127, which in 2003 was used only for gamma spectroscopy of sealed material, but where the ducts continue to be contaminated with low levels of tritium, probably from past handling of hazardous waste. Other rooms in Building 75 were used for tritium calorimetry. In 2003, emissions from these locations were sampled and analyzed monthly for tritium.

Building 75A was also a part of the former Hazardous Waste Handling Facility, and in 2003, it was used for storage of tritium-contaminated items. In 2003, Building 75A was classified as Category V, for which the radionuclide inventory was controlled by radiation work authorizations and permits and by periodic assessments.

At the former NTLF, for many years Berkeley Lab conservatively estimated the dose to the site-wide MEI by not taking into account the momentum effect of effluent velocity (that is, stack effluent exit velocity was set to zero) in the CAP88-PC computer model. As discussed with personnel from EPA Region 9, starting in 1998 Berkeley Lab began including the momentum effect (that is, the actual stack effluent exit velocity was applied) in the CAP88-PC computer model to more closely reflect the physical conditions of the hillside stack exhaust (EPA 2002). Since 2001, the effluent exit velocity and stack diameter of each of the two former NTLF stacks have also been taken into account. In 2003, a third stack representing the remaining release points in Buildings 75 and 75A was used in the computer model. Although CAP88-PC allows the use of effluent exit velocity and stack diameter specific to each stack, the program assumes conservatively that all are at the location of the hillside stack, which is closest to the local MEI at the UC Lawrence Hall of Science.

A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 15.

Table 15 Buildings 75 and 75A Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)	Annual emission (Ci/y)[b]	Local MEI dose (mrem/y)[c]	Percent of total dose (%)
8.5	110	NW	UC Lawrence Hall of Science	H-3	3.19E-02	2.7E-04	100
6.7				H-3	7.18E-02		
7.0				H-3	9.37E-04		
				Total	**2.7E-04**		**100%**

[a] MEI = maximally exposed individual
[b] 1 Ci = 3.7×10^{10} Bq
[c] 1 mrem = 1.0×10^{-2} mSv

1.3.11 Building 85 (Hazardous Waste Handing Facility)

Radioactive and hazardous waste generated by Berkeley Lab research and support operations is sent to Building 85, where it is processed for shipping to off-site disposal facilities. In 2003, this building had two stacks equipped with continuous air sampling systems to collect alpha- and beta-emitting radionuclides, ^{14}C, ^{125}I, and tritium. To estimate the dose, ^{232}Th and ^{90}Sr were used as surrogates for alpha- and beta-emitting radionuclides, respectively. A summary of the CAP88-PC source term input parameters and effective dose equivalent from Building 85 is presented in Table 16.

Table 16 Building 85 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
16	210	SSE	UC Berkeley	C-14	6.2E-03	1.7E-04	47.3
				H-3	5.2E-02	5.0E-05	13.8
				I-125	2.1E-07	8.9E-07	0.2
				Gross alpha (Th-232)	9.9E-08	1.4E-04	38.4
				Gross beta (Sr-90)	2.4E-07	1.1E-06	0.3
				Total	**3.6E-04**	**100%**	

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv

1.3.12 Building 88 (88-Inch Cyclotron)

The 88-Inch Cyclotron at Building 88 accelerates beams from hydrogen to uranium in support of national programs in nuclear science, biology, medicine, and industrial applications. The energy of the cyclotron's beam depends on the ion being accelerated. For example, protons, which are light ions, are accelerated to 65 MeV; ^{209}Bi, a heavy ion, is accelerated to 1.6 GeV. The normal operating current of the beam is 100 μA.

The ions accelerated in the cyclotron may be radioactive, and the targets that the ion beam strikes may also be radioactive. Use of these radionuclides is internally approved by radiation work authorizations. In addition, the cyclotron produces neutrons during its operation, which can activate the components of air. The major air activation products produced by the cyclotron are ^{11}C, ^{13}N, and ^{15}O, all positron-emitting radionuclides.

The cyclotron is enclosed within a vault, and the vault is ventilated by an exhaust system to a roof stack. Emissions from the roof stack are monitored by a real-time positron detector. For projects that accelerate radioactive gases, an effluent-capture system in the cyclotron pit collects and stores vacuum pump exhaust in holding bags until the short-lived radionuclides have decayed.

Emissions in 2003 were estimated based on radionuclide receipts (^{238}U was the only radionuclide received), emissions measurements from three stacks that were sampled for alpha- and beta-emitting radionuclides, and measurements of positron-emitting radionuclides from the stack that exhausts the cyclotron vault. To estimate the dose, all positron-emitting radionuclides from this facility were assumed to be ^{11}C, and alpha- and beta-emitting radionuclides were assumed to be ^{232}Th and ^{90}Sr, respectively. Carbon-11 is an appropriate surrogate for radioisotopes of nitrogen and oxygen because it has metabolic and radiological properties that are similar to the other radionuclides. A summary of the CAP88-PC source term input parameters and the effective dose equivalent for this source is presented in Table 17.

Table 17 Building 88 Source Characteristics and Dose Impacts

Release height (m)	Local MEI[a] distance (m)	Local MEI dir.	Local MEI description	Radionuclide (surrogate)[b]	Annual emission (Ci/y)[c]	Local MEI dose (mrem/y)[d]	Percent of total dose (%)
13	110	W	Residence	U-238[e]	4.3E-16	3.5E-13	< 0.1
				Positron (C-11)	2.4E-01	2.2E-04	77.0
				Gross alpha (Th-232)	1.3E-07	6.6E-05	22.6
				Gross beta (Sr-90)	4.5E-07	6.7E-07	0.2
					Total	**2.9E-04**	**100%**

[a] MEI = maximally exposed individual
[b] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[c] 1 Ci = 3.7×10^{10} Bq
[d] 1 mrem = 1.0×10^{-2} mSv
[e] Includes progeny

AIR EMISSIONS DATA

Source and emission control information are summarized in Table 18.

Table 18 Sources and Emission Controls In 2003

Source	Number of release points	Type of control	Efficiency (%)	Distance to nearest member of public[a]
Point sources				
Building 1	9	None[b]	NA[c]	10 m (classrooms in same building)
Building 3	2	None[b]	NA	30 m (UC Berkeley)
Building 71	4	None	NA	190 m (Residence)
Building 72	2	None	NA	230 m (UC Berkeley)
Building 85	2	HEPA[d] TEDA-DAC[e]	>99 >75	210 m (UC Berkeley)
Building 88	14	HEPA TEDA-DAC	>99 >75	110 m (Residence)
Group sources				
Buildings 6/16	10	None[f]	NA	370 m (UC Lawrence Hall of Science)
Buildings 26/76	4	HEPA	>99	250 m (UC Lawrence Hall of Science)
Buildings 55/56/64	17	HEPA TEDA-DAC[g]	>99 >75	250 m (Residence)
Buildings 70/70A	43	HEPA None[h]	>99 NA	270 m (UC Berkeley Dormitory)
Buildings 74/83/84	30	HEPA TEDA-DAC None	>99 >75 NA	160 m (UC Berkeley)
Buildings 75/75A	11	None	NA	110 m (UC Lawrence Hall of Science)

[a] 1 m = 3.281 ft
[b] Emissions are from Berkeley Lab fume hoods, which do not require filtration for the small radionuclide amounts used.
[c] Not applicable
[d] High-efficiency particulate air (HEPA)
[e] Tetraethylene diamine (TEDA)-doped activated carbon traps
[f] Radionuclides emitted from accelerators are short-lived air activation products, for which emission control is impractical.
[g] TEDA-DAC filters at Building 55 only
[h] Stacks included in this group vent a number of laboratories whose research employs microcurie and millicurie quantities (between 3.7×10^4 and 3.7×10^7 Bq) of a number of actinides. The most conservative dose-equivalent representative of the actinides was used.

Quantities of radionuclides potentially emitted from Berkeley Lab sources in 2003 are presented in Table 19.

Table 19 Airborne Radioactivity Potentially Emitted In 2003

Radionuclide (surrogate)[a]	Activity potentially emitted		Total (%)
	(Ci/y)	(Bq/y)	
F-18	3.59E+00	1.33E+11	89.9
C-11	2.42E-01	8.95E+09	6.1
H-3	1.56E-01	5.77E+09	3.9
C-14	6.34E-03	2.35E+08	0.2
I-125	2.98E-04	1.10E+07	< 0.1
P-32	2.18E-04	8.08E+06	< 0.1
Tc-99m	1.78E-04	6.59E+06	< 0.1
I-123	1.00E-04	3.70E+06	< 0.1
S-35	2.05E-05	7.59E+05	< 0.1
N-13	1.80E-05	6.66E+05	< 0.1
I-131	1.00E-05	3.70E+05	< 0.1
Beta (Sr-90)	3.76E-06	1.39E+05	< 0.1
P-33 (P-32)	2.00E-06	7.40E+04	< 0.1
Pa-233	1.64E-06	6.07E+04	< 0.1
Np-237	1.12E-06	4.14E+04	< 0.1
Tc-99	1.05E-06	3.89E+04	< 0.1
Alpha (Th-232)	8.32E-07	3.08E+04	< 0.1
Zr-95[b]	5.00E-07	1.85E+04	< 0.1
Tl-201 (Ga-67)	4.00E-07	1.48E+04	< 0.1
U-238[b]	1.72E-07	6.36E+03	< 0.1
U-233	1.70E-07	6.29E+03	< 0.1
Am-243	1.00E-07	3.70E+03	< 0.1
O-15	9.40E-08	3.48E+03	< 0.1
Pu-238	2.86E-08	1.06E+03	< 0.1
Th-229	1.40E-08	5.18E+02	< 0.1
Th-232[b]	1.25E-08	4.63E+02	< 0.1
Tm-170 (Hf-181)	1.00E-08	3.70E+02	< 0.1
Y-90	8.00E-09	2.96E+02	< 0.1
Hf-175 (Pb-210)	5.64E-09	2.09E+02	< 0.1
Am-241	5.00E-09	1.85E+02	< 0.1
Eu-152	5.00E-09	1.85E+02	< 0.1
Bi-207 (Hf-181)	5.00E-09	1.85E+02	< 0.1
Cs-137[b]	4.76E-09	1.76E+02	< 0.1
Pu-239	4.60E-09	1.70E+02	< 0.1
Sr-90[b]	4.06E-09	1.50E+02	< 0.1
Ho-166m	4.00E-09	1.48E+02	< 0.1
Fe-59	2.48E-09	9.17E+01	< 0.1
U-235	1.29E-09	4.77E+01	< 0.1
Ra-226b	1.00E-09	3.70E+01	< 0.1

Table 19 Airborne Radioactivity Potentially Emitted In 2003 (continued)

Radionuclide (surrogate)[a]	Activity potentially emitted (Ci/y)	Activity potentially emitted (Bq/y)	Total (%)
Tl-204 (Pb-214)	1.00E-09	3.70E+01	< 0.1
Ta-182 (Hf-181)	1.00E-09	3.70E+01	< 0.1
Na-22	1.00E-09	3.70E+01	< 0.1
Sc-46	6.95E-10	2.57E+01	< 0.1
Cf-249 (Cm-245)	5.00E-10	1.85E+01	< 0.1
U-234	4.80E-10	1.78E+01	< 0.1
Ra-228[b]	4.47E-10	1.65E+01	< 0.1
Zr-88 (Ag-110m)	3.00E-10	1.11E+01	< 0.1
Ca-45 (Sr-90)	1.33E-10	4.92E+00	< 0.1
U-232	1.00E-10	3.70E+00	< 0.1
Mn-54	1.00E-10	3.70E+00	< 0.1
Cm-248	7.13E-11	2.64E+00	< 0.1
Co-60	6.44E-11	2.38E+00	< 0.1
Rh-101 (Mo-93)	5.00E-11	1.85E+00	< 0.1
Ce-141	2.76E-11	1.02E+00	< 0.1
Cs-134	2.53E-11	9.34E-01	< 0.1
Cm-244	1.40E-11	5.18E-01	< 0.1
Rb-86	8.44E-12	3.12E-01	< 0.1
Cf-252	5.00E-12	1.85E-01	< 0.1
Zn-65	3.16E-12	1.17E-01	< 0.1
Au-198 (Ir-192)	2.99E-12	1.11E-01	< 0.1
Sr-89	1.76E-12	6.52E-02	< 0.1
Ba-133	1.33E-12	4.92E-02	< 0.1
Th-230[b]	1.33E-12	4.91E-02	< 0.1
Np-239	1.40E-13	5.18E-03	< 0.1
Cm-243	1.30E-13	4.81E-03	< 0.1
Ce-144[b]	1.34E-14	4.96E-04	< 0.1
Co-57	8.70E-15	3.22E-04	< 0.1
Xe-133	8.00E-15	2.96E-04	< 0.1
Nb-95	4.30E-15	1.59E-04	< 0.1
Fe-55	2.01E-15	7.45E-05	< 0.1
Sb-124	2.00E-15	7.40E-05	< 0.1
Sb-125	1.90E-15	7.03E-05	< 0.1
Ni-63	1.41E-15	5.21E-05	< 0.1
Be-7	1.34E-15	4.96E-05	< 0.1
Sb-122 (Mo-99)	6.00E-16	2.22E-05	< 0.1
Ru-106[b]	6.00E-17	2.22E-06	< 0.1
Total	**3.99E+00**	**1.47E+11**	**100%**

[a] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose
[b] Includes progeny

3

DOSE ASSESSMENTS

3.1 DESCRIPTION OF DOSE MODEL

To comply with NESHAP regulations and meet DOE guidance, the EPA atmospheric dispersion and radiation dose calculation computer code, CAP88-PC, Version 2.0, was used to calculate the effective dose equivalent to an individual within each population segment at various distances and from various release points. A total of 16 CAP88-PC individual runs were executed to model the 12 point and group sources described in Section 1. (Multiple runs were required for some sources because the number of radionuclides potentially emitted from these sources exceeded the maximum number that CAP88-PC can model [36].) For 2003, the group source comprising Buildings 55, 56, and 64 was identified as the most significant source of airborne radionuclides emitted from Berkeley Lab. This source was responsible for 72% of the total dose to the site-wide MEI, which was determined to be at the UC Lawrence Hall of Science. Therefore, the distance and direction to the Lawrence Hall of Science was specified in each of the 16 individual CAP88-PC runs. The reported effective dose equivalent to the site-wide MEI includes contributions from all 16 CAP88-PC runs (Table 20).

Collective population dose is calculated as the average radiation dose to a person in a specified area, multiplied by the number of people in that area. In past years, Berkeley Lab has used CAP88-PC to evaluate the collective dose that would result if all airborne radionuclides from Berkeley Lab activities were emitted from the hillside stack that exhausts the former NTLF. This was valid because until 2003, the greatest source of radioactive air emissions was the NTLF. Following closure of the NTLF, however, this approach was reconsidered. In 2003, Berkeley Lab determined that, in accordance with DOE and EPA guidance documents, a hypothetical, centrally located stack with conservative stack parameters would be appropriate for use in calculating collective dose (Wahl 2003). Thus, all radionuclides potentially emitted in 2003 (Table 19) were assumed to be released from a centrally located stack that is 16 m high, is 0.3 m in diameter, and has an exit velocity of 4.1 m/s. Because CAP88-PC can only model 36 radionuclides at a time, the population dose assessment was performed with four population runs, and the results of the four runs were summed. A summary of the collective dose assessment attributed to each potentially emitted radionuclide is given in Table 21.

Input to the CAP88-PC calculations of individual and population dose were reviewed and verified by an internal peer reviewer. The reviewer followed EHS Procedure 217, Auditing Radionuclide

NESHAP Compliance, to verify source terms used as input into CAP88-PC and to check accuracy and completeness of CAP88-PC output data presented in this report. The reviewer determined that doses were calculated in compliance with Berkeley Lab procedures and with 40 CFR 61, Subpart H.

In addition, the CAP88-PC code was validated by performing a sample assessment. The output of the sample assessment was compared to output provided in the CAP88-PC, Version 2, users' guide. The two outputs were identical, indicating that the code performed as intended.

Table 20 Summary of Dose Assessment from All Berkeley Lab Sources

			Relative to nearest off-site member of public[a]				Relative to UC Lawrence Hall of Science[b]			
Building number	**Building name/function**	**Release height (m)**	**Distance (m)**	**Direction**	**Description**	**Dose (mrem/y)[c]**	**Distance (m)**	**Direction**	**Dose (mrem/y)**	**Percent of total dose (%)**
1	Donner Lab at UC Berkeley	18	10	ESE	UC Berkeley	1.4×10^{-5}	990	ENE	2.1×10^{-5}	0.2
3	Calvin Lab at UC Berkeley	15	30	S	UC Berkeley	4.1×10^{-7}	1060	NE	3.8×10^{-7}	< 0.1
6/16	Advanced Light Source (ALS)/ Accelerator & Fusion Research	9	350	NNE	UC Lawrence Hall of Science	1.3×10^{-8}	350	NNE	1.3×10^{-8}	< 0.1
26/76	Radioanalytical Lab	8	250	N	UC Lawrence Hall of Science	8.6×10^{-7}	250	N	8.6×10^{-7}	< 0.1
55/56/64	Center for Functional Imaging/Biomedical Isotope Facility/Life Sciences	16	250	NNW	Residence	6.7×10^{-3}	460	E	7.7×10^{-3}	81.1
70/70A	Nuclear/Chemical/Life/ Earth/Environmental Sciences	16	270	WSW	UC Berkeley Dormitory	3.9×10^{-4}	530	ENE	9.3×10^{-4}	9.8
71	Accelerator & Fusion Research	13	190	NNW	Residence	1.3×10^{-15}	310	ESE	2.4×10^{-15}	< 0.1
72	Low-Background Facility	3	230	SSW	UC Berkeley	2.9×10^{-12}	500	NW	3.3×10^{-12}	< 0.1
74/83/84	Human Genome Facility/Life Sciences	7	160	SSE	UC Berkeley	4.2×10^{-5}	690	WNW	3.7×10^{-5}	0.4
75/75A	Former National Tritium Labeling Facility/Hazardous Waste Facility	8.5[d] 6.7[e] 7.0[f]	110	NW	UC Lawrence Hall of Science	2.7×10^{-4}	110	NW	2.7×10^{-4}	2.6
85	New Hazardous Waste Handling Facility	16	210	SSE	UC Berkeley	3.6×10^{-4}	570	WNW	4.0×10^{-4}	4.2
88	88-Inch Cyclotron	13	110	W	Residence	2.9×10^{-4}	690	ENE	1.6×10^{-4}	1.7
								Total	**9.5×10^{-3}**	**100%**

[a] Local maximally exposed individual (MEI)
[b] Site-wide MEI
[c] 1 mrem = 1.0×10^{-2} mSv
[d] Former NTLF hillside stack
[e] Former NTLF rooftop stack
[f] Other Building 75/75A stacks

Table 21 Summary of Collective Dose to the Population within 80 km of Berkeley Lab

Radionuclide[a] (surrogate)	Collective dose (person-rem/y)[b]	Percent of total (%)
F-18	8.7E-02	57.1
Np-237	3.0E-02	19.5
Alpha (Th-232)	1.6E-02	10.7
U-238[c]	5.3E-03	3.5
Am-243	2.9E-03	1.9
H-3	2.9E-03	1.9
C-14	2.2E-03	1.4
C-11	1.8E-03	1.2
U-233	1.2E-03	0.8
I-125	1.1E-03	0.7
Th-229	5.3E-04	0.3
Pu-238	4.9E-04	0.3
Th-232[c]	4.6E-04	0.3
Am-241	1.5E-04	0.1
Beta (Sr-90)	1.3E-04	0.1
P-32	1.3E-04	0.1
Pu-239	8.5E-05	0.1
I-131	2.0E-05	< 0.1
Cf-249 (Cm-245)	1.5E-05	< 0.1
U-235	8.8E-06	< 0.1
Ho-166M	8.0E-06	< 0.1
Zr-95[c]	7.9E-06	< 0.1
Cm-248	7.9E-06	< 0.1
Ra-228[c]	7.4E-06	< 0.1
Tc-99	6.2E-06	< 0.1
Hf-175 (Pb-210)	5.5E-06	< 0.1
U-234	3.4E-06	< 0.1
I-123	3.3E-06	< 0.1
U-232	2.6E-06	< 0.1
Eu-152	2.3E-06	< 0.1
Pa-233	2.1E-06	< 0.1
Ra-226[c]	2.1E-06	< 0.1
S-35	2.0E-06	< 0.1
Cs-137[c]	1.9E-06	< 0.1
Tc-99m	1.4E-06	< 0.1
P-33 (P-32)	1.2E-06	< 0.1
Cm-244	2.2E-07	< 0.1
Na-22	2.2E-07	< 0.1
Sr-90[c]	1.4E-07	< 0.1
N-13	7.0E-08	< 0.1
Cf-252	4.2E-08	< 0.1
Tl-201 (Ga-67)	3.8E-08	< 0.1
Tm-170 (Hf-181)	3.6E-08	< 0.1

Table 21 Summary of Collective Dose to the Population within 80 km of Berkeley Lab (continued)

Radionuclide[a] (surrogate)	Collective dose (person-rem/y)[b]	Percent of total (%)
Co-60	2.9E-08	< 0.1
Zr-88 (Ag-110m)	2.4E-08	< 0.1
Th-230[c]	2.1E-08	< 0.1
Bi-207 (Hf-181)	1.8E-08	< 0.1
Fe-59	1.6E-08	< 0.1
Sc-46	1.4E-08	< 0.1
Ca-45 (Sr-90)	4.6E-09	< 0.1
Y-90	4.0E-09	< 0.1
Ta-182 (Hf-181)	3.6E-09	< 0.1
Cs-134	3.5E-09	< 0.1
Mn-54	3.0E-09	< 0.1
Cm-243	2.6E-09	< 0.1
Rh-101 (Mo-93)	3.6E-10	< 0.1
Ba-133	1.9E-10	< 0.1
Zn-65	6.3E-11	< 0.1
O-15	5.6E-11	< 0.1
Au-198 (Ir-192)	2.7E-11	< 0.1
Ce-141	2.4E-11	< 0.1
Tl-204 (Pb-214)	1.5E-11	< 0.1
Rb-86	8.0E-12	< 0.1
Sr-89	1.1E-12	< 0.1
Ce-144[c]	3.0E-13	< 0.1
Sb-125	9.1E-14	< 0.1
Co-57	4.2E-14	< 0.1
Sb-124	2.8E-14	< 0.1
Np-239	2.7E-14	< 0.1
Nb-95	1.6E-14	< 0.1
Ru-106[c]	2.1E-15	< 0.1
Be-7	4.5E-16	< 0.1
Fe-55	2.8E-16	< 0.1
Ni-63	2.4E-16	< 0.1
Sb-122 (Mo-99)	1.7E-16	< 0.1
Xe-133	1.5E-17	< 0.1
Total	**1.5E-01**	**100%**

[a] For radionuclides not listed in CAP88-PC library, surrogate radionuclides (in parentheses) were used to model dose

[b] 1 person-rem = 1×10^{-2} person-Sv

[c] Includes progeny

3.2 SUMMARY OF INPUT PARAMETERS

Run options for CAP88-PC individual dose assessments include distances to receptors. Twenty such distances were specified, including distance to the nearest local member of the public, the residence nearest the 88-Inch Cyclotron, the residence nearest the Building 56 accelerator, and the Lawrence Hall of Science (the MEI). To estimate population dose, the population file prepared in 2002 based on the LandScan Global Population Database for 2001 was used (Gallegos 2002).

Meteorological data were compiled from on-site data for 2003. Berkeley Lab began collecting this data in early 1994 at a 66-ft (20-m) tower located in the central portion of the Laboratory. The 2003 meteorological data is maintained in the NESHAP files.

Source data include stack height, diameter, and exit velocity. Momentum plume rise was chosen for all sources. Release heights are shown in Table 20. For all point and group sources (except Buildings 75 and 75A), other stack input parameters were 4 in. (0.1 m) diameter and 0 m/s exit velocity. At the former NTLF in Building 75, input parameters for the hillside stack were 3 ft (0.91 m) diameter and 25.1 ft/s (7.66 m/s) exit velocity and for the roof stack were 1.7 ft (0.53 m) diameter and 18.7 ft/s (5.69 m/s) exit velocity. For remaining sources in Building 75 and in Building 75A, the default parameters of 4 in. (0.1 m) diameter and 0 m/s exit velocity were used.

Agricultural data were the CAP88-PC default values for an urban scenario, which is appropriate for the Berkeley Lab site.

Nuclide data for the 2003 radioactive air emissions were both measured and conservatively derived based on the inventory received or used during the year, and data are shown in Table 19 in Section 2. Surrogates were chosen as described in Section 1.3. To estimate population dose, four CAP88-PC runs were performed using stack parameters of a hypothetical, centrally located stack (discussed in Section 3.1), with the source term replaced by all the radionuclides listed in Table 19. One run included all radionuclides in Table 19 through ^{207}Bi, the second run included radionuclides from ^{137}Cs through ^{141}Ce, the third run included radionuclides from ^{134}Cs through ^{106}Ru, and the fourth run included ^{238}U, ^{232}Th, and ^{175}Hf. The results of the four runs were summed.

3.3 COMPLIANCE ASSESSMENT

This compliance assessment used the computer code CAP88-PC, Version 2.0, to calculate the effective dose equivalent to a site-wide MEI. This exposure represents the sum of impacts from all 12 sources modeled to that location (the MEI at the UC Lawrence Hall of Science). A summary of the dose assessment for each source is presented in Table 20.

Effective dose equivalent: 0.01 mrem/year (1.0×10^{-4} mSv/year)

Location of site-wide MEI: UC Lawrence Hall of Science at 460 m east of Building 64

3.4 CERTIFICATION

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein, and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (See, 18 U. S. C. 1001).

Signature: Robin Wendt Date: 5/25/04

Robin Wendt
Acting Division Director, Environment, Health, and Safety Division

Signature: R. Nolan Date: 5/28/04

Richard H. Nolan
Director, DOE Berkeley Site Office

ADDITIONAL INFORMATION

4.1 ADDITIONS OR MODIFICATIONS

There were no facility additions or modifications in 2003. There were, however, changes in emissions measurement and reporting in 2003, based primarily on changes in work authorized. Changes from last year's report include addition and deletion of stack sampling locations.

4.1.1 New Sampling Locations

One new sampling location was added in 2003. Results of sampling at this location are included in the source descriptions (Section 1.3.10).

- At Building 75, the sampler for the hillside stack, which exhausts Room 103 of the former NTLF, was moved to a location nearer the stack exit. This allows for more accurate measurement of the small amount of residual tritium in the ductwork. Sampling at this location began in November 2003.

4.1.2 Deleted Sampling Locations

In 2003, three sampling locations were deleted.

- At Building 1, work with radionuclides was no longer performed in Room 267, so sampling of the Room 276 fume hood stack was discontinued in November 2003.
- At Building 70, glove boxes in Room 203 were decontaminated, decommissioned, and removed, so sampling of the stack that exhausted them was discontinued in May 2003.
- At the former NTLF in Building 75, real-time monitoring was discontinued in May 2003 after emissions had decreased by two orders of magnitude and EPA confirmed that real-time monitoring was not required. In addition, the rooftop sampling location for the Room 103 exhaust was discontinued after sampling began at the new hillside location.

4.2 UNPLANNED RELEASES

There were no unplanned releases in 2003.

4.3 DIFFUSE EMISSIONS

In 2003, no area sources were identified that potentially presented a source of fugitive emissions to the public.

SUPPLEMENTAL INFORMATION

5.1 DOSE ESTIMATE

Provide an estimate of collective effective dose equivalent (person-rem/y) for 2003 releases.

The estimated collective effective dose equivalent to persons living within 80 km of Berkeley Lab is 0.15 person-rem (0.0015 person-Sv) attributable to 2003 Berkeley Lab airborne emissions (see Table 21).

5.2 RADON EMISSIONS

Provide information on the status of compliance with Subparts Q and T of 40 CFR Part 61, if applicable. Although exempt from Subpart H, provide information on ^{220}Rn emission from sources containing ^{232}U and ^{232}Th where emissions potentially can exceed 0.1 mrem/y (10^{-6} Sv/y) to the public or 10% of the nonradon dose to the public. Provide information on nondisposal/nonstorage sources of ^{222}Rn emissions where emissions potentially can exceed 0.1 mrem/y (10^{-6} Sv/y) to the public or 10% of the nonradon dose to the public.

Subparts Q and T of 40 CFR 61 are not applicable to Berkeley Lab, as the Laboratory does not process, manage, or possess uranium mill tailings, ^{226}Ra, ^{232}U, or ^{232}Th, in quantities that could produce an impact of 0.1 mrem/y (1×10^{-6} Sv/y) to a member of the public.

5.3 EMISSION POINTS

For the purpose of assessing facility compliance with the NESHAP effluent monitoring requirements of Subpart H under Section 61.93(b), give the number of emission points subject to the continuous monitoring requirements, the number of these emission points that do not comply with the Section 61.93(b) requirements, and if possible, the cost for upgrades. Describe site periodic confirmatory measurement plans. Indicate the status of the QA program described by Appendix B, Method 114.

In 2003, no release points produced emissions exceeding 0.1 mrem/y (1.0×10^{-3} mSv/y) and no sources were subject to continuous monitoring requirements. Berkeley Lab's sampling, monitoring, and analytical methods fully conform to Section 61.93(b) requirements. Berkeley Lab has a) identified all release points and evaluated emissions, b) categorized release points by effective dose equivalent, and

c) suggested suitable measurement methodology for each point. Periodic confirmatory measurements were conducted in accordance with the EPA-approved NESHAP compliance strategy established as part of Berkeley Lab's fulfillment of its NESHAP FFCA (Table 2).

The program meets or exceeds provisions contained in Appendix B, Method 114. The current Berkeley Lab *Environmental Monitoring Plan* and Environmental Services Group procedures contain quality assurance elements consistent with Method 114. Berkeley Lab's *Quality Assurance Project Plan for Radionuclide NESHAP* was originally developed and approved in August 1994 and was most recently revised in May 2004.

REFERENCES

ICRP 1996: International Commission on Radiological Protection. Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 4, Inhalation Dose Coefficients, ICRP 71, Elsevier Science, Inc., Tarrytown, NY (1996).

DOE 1991: Department of Energy. Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance, DOE/EH-0173T, Washington, D.C. (January 1991).

DOE 1993: Department of Energy. "Guidance for the Preparation of the 1992 Radionuclide Air Emissions Annual Report under Subpart H of 40 CFR Part 61," DOE memorandum (1993).

Donahue 1991: Donahue, R. "Air Activation in the ALS Storage Ring," Health Physics Note #191, Lawrence Berkeley National Laboratory, Berkeley, CA (April 8, 1991).

EPA 2002: Rosenblum, S., and R. Lessler (EPA). Telephone conversation with S. Black (DOE), and R. Pauer, L. Wahl, M. Ruggieri (LBNL) (May 15, 2002).

Wahl 2003: Wahl, L. "Annual Calculation of Collective Dose from Airborne Radionuclides," ES-03-037, memo to file documenting stack parameters for collective dose calculations (October 9, 2003).

Gallegos 2002: Gallegos, G., "Estimating Populations for Collective Dose Calculations," Health Physics, Volume 83, Number 2, pages 283–286 (August 2002).

ATTACHMENT

7.1 ATTACHMENT A: EPA CONFIRMATION OF DISCONTINUATION OF REAL-TIME TRITIUM MONITORING

In June 2003, Berkeley Lab recognized that real-time monitoring for tritium at the former NTLF was no longer appropriate, and requested confirmation from EPA that the real-time system was not needed for NESHAP compliance. EPA responded with a letter confirming that real-time monitoring could be discontinued. The text of Berkeley Lab's request and EPA's response follow.

Environment, Health & Safety Division
Environmental Services Group

June 3, 2003
ES-03-023

Jack Broadbent
Director, Air Division
United States Environmental Protection Agency, Region 9
75 Hawthorne Street
San Francisco, CA 94105-3901

Subject: Confirmation that real-time monitoring for tritium may be discontinued at Lawrence Berkeley National Laboratory

Dear Mr. Broadbent:

Tritium emissions from the former National Tritium Labeling Facility (NTLF) at the Lawrence Berkeley National Laboratory (LBNL) are regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAPs or NESHAP) program of the Clean Air Act. NESHAPs oversight is performed at LBNL by the EPA, Region 9. Although the NTLF was closed in December 2001, LBNL continues to monitor air emissions from the NTLF exhaust system as required by NESHAPs using a silica gel sampling system. Real-time monitoring was also used to determine when pulse releases occurred and continues to be in operation. We would like to discontinue its operation and request confirmation from EPA that the real-time system is not needed for NESHAPs compliance purposes.

While the NTLF was in operation, most of the NTLF tritium releases were generated as a result of labeling activities performed in room 103. The exhaust from this room is emitted from a stack that is located on a hillside next to the building, and two monitoring systems were installed to measure these emissions:

1. To demonstrate compliance with NESHAPs regulations (40 CFR 61 subpart H), LBNL has continuously collected stack emission samples using silica gel columns that are analyzed offline.

2. In addition to sampling in accordance with NESHAPs, the LBNL has also continuously operated a real-time tritium monitoring system to provide timely feedback regarding pulse emissions.

Silica gel sampling with offline analysis has been used to demonstrate NESHAP compliance because it is a much more sensitive and reliable method for measuring airborne tritium than real-time monitoring.

Following closure of the NTLF in December 2001, the tritium inventory was removed from room 103. Clean-up of the NTLF was completed in October of 2002, including the removal of all research apparatus and equipment. Since then, tritium emissions from room 103 have decreased by two orders of magnitude, to levels well below the detection sensitivity of the real-time monitoring system, and the likelihood of a tritium pulse release is extremely remote under the present conditions. Tritium emissions are currently less than 0.1 curie per year, which results in a dose of less than 0.01% of the EPA public health standard (10 mrem per year) to the maximally exposed individual. It is believed that the small, constant release that we are now measuring is due to the slow off-gassing of tritium from the internal surfaces of the building's exhaust system components. For NESHAPs compliance, we continue to monitor tritium emissions from

the hillside stack using silica gel sampling equipment and report these results in the NESHAPs Air Emission Annual Report and the annual LBNL Site Environmental Report.

Based on our understanding of the NESHAPs regulations, the continued operation of the silica gel sampling for the hillside stack fully satisfies the requirements of 40 CFR, Subpart H and the additional real-time monitoring may be discontinued at our discretion. However, we would like to have EPA confirm our understanding prior to discontinuing the operation of the real-time equipment. If you have any questions, please feel free to contact me at (510) 486-7614.

Sincerely,

Ron Pauer
Environmental Services Group Leader

cc: M. Bandrowski, EPA
S. Black, DOE
R. Lessler, EPA
D. McGraw, LBNL
D. Nolan, DOE
S. Rosenblum, EPA
M. Ruggieri, LBNL
C. Schwab, DOE
L. Wahl, LBNL
R. Wendt, LBNL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

June 19, 2003

Ron Pauer
Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS-75B-117
Berkeley, CA 94720

Subject: Confirmation that real-time monitoring for tritium may be discontinued at LBNL

Dear Mr. Pauer:

In your letter of June 3, 2003 (enclosed) you requested confirmation from EPA that your real-time monitoring system is not needed for NESHAP compliance purposes. This is to confirm that the continued operation of the silica gel sampling for the hillside stack of the former NTFL fully satisfies the requirement of 40 CFR 61, Subpart H and that the additional real-time monitoring may be discontinued at your discretion.

Sincerely,

Jack P. Broadbent
Director, Air Division

Enclosure

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